The Emergence of New Industries in Space: An evolutionary understanding of industry emergence from a geographical perspective

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Abstract:

This paper claims that in the field of economic geography, research questions about how new industries emerge and the degree to which their emergence are anchored in regional economies are less commonly studied than concepts of for example localisation economies and clusters. Consequently, there is little knowledge regarding where new industries emerge and why new industries emerge where they do. Therefore there is a need to establish a more rigorous research agenda that will elucidate some of the more fundamental elements that contribute to the creation of new industries.

It is the objective of this paper to contribute to the recently emerged evolutionary thinking in economic geography (Boschma, Martin 2007, Boschma, Frenken 2006, Grabher 2009) with a conceptual clarification of industry emergence. The paper first reviews the definition of emerging industries as it appears in the field of industrial organisational economics (Porter 1980) and in evolutionary economics (Dosi 1984, Nelson, Winter 1982). Second, the paper discusses the particularity that characterizes the temporal scope of industry emergence and it is claimed that the literature often lack attention to periods that precede the conventional industry life cycle (Forbes, Kirsch 2010). Third, the paper reviews the most commonly used approaches to industry emergence and industry evolution in economic geography and concludes that studies in economic geography are subject to the same lack of attention towards industry emergence. Finally, the paper draws on the recent conceptual framework of 'regional branching' that is able to capture the emergence of new industries in their geographical context. Regional branching builds on the evolutionary understanding of industry development and modifies previous understanding of industry emergence, which has characterized the field of economic geography. In particular, the framework builds on a critique of the predominant role previous theories have ascribed to chance events.

Keywords: Emerging industry, emerging technology, geography, evolutionary economics

Introduction

Emerging technologies are intriguing to many people because they are associated with new products that forecast changes for society and for everyday life. This fascination is not only the case for modern technology, such as the mobile cellular phone, computers or the Internet. The Danish author and Nobel laureate Johannes V. Jensen surrendered unconditionally when standing face to face with a contemporary steam engine at the World's Fair in Paris in 1900. As he wrote in his 1901 novel 'The Gothic Renaissance', "*No living being can comprehend the force in the cylinders of a steam engine, no one can imagine the greatness in the movement of the smooth piston rod...*" (Jensen 2000). Although new technologies have also been met with scepticism, it seems that emerging technologies always have fascinated people by their inherent potential to change the world.

The development of new technologies also generates the potential to create new industries or disrupt existing ones (Dosi 1984, Dosi 1988, Day, Schoemaker et al. 2000). While emerging technologies often are defined as science-based innovations (Day, Schoemaker et al. 2000) emerging industries can be defined as a group of firms that explore and exploit the economic potential of an emerging technology. New industry development is motivated by the desire to create value out of technological potential, and this development may attract both new and incumbent firms. If technological potentials are realised and a new industry starts taking shape, new technologies not only have the potential to bring about great changes for society and for everyday life but also for the geographical distribution of economic activity. As new industries are associated with entrepreneurial activity, creating jobs, and increasing exports, new industries benefit the regions[1] where they are localised. Conversely, new industries may also disrupt existing industries and potentially cause economic decline in other regions.

For these reasons, emerging industries attract a good deal of interest from both policy and academia. Particularly in a globalised economy with strong competition between countries and regions, the interest in emerging technology-based industries has increased, as emerging industries are perceived as platforms for future economic growth in the geographical territory where the new industry is localised.

Consequently, regional authorities across the world design regional innovation policies intended to attract high technology industries to locate or develop within their borders. Such policies often results in regional strategies to develop ICT clusters, Medicon Valleys, or Hydrogen Communities. These regions design various policies, such as the promotion of R&D networks, public-private partnerships, demonstration projects, and public purchase initiatives to induce technological development and create first-mover advantages for their region.

While there is a good deal of research on the dynamics of the emergence of new industries in general, there is notably little theory to support regional strategies to promote the

[1] Here and in the following section, 'regions' refer to districts or territories at the sub-national level.

emergence of new industries (Feldman, Lendel 2010, Kenney, von Burg 2001). This scarcity is the research gap that this paper aims to address.

In the field of economic geography, research questions about how new industries emerge and the degree to which their emergence are anchored in regional economies are less commonly studied than concepts of localisation economies. Consequently, there is little knowledge regarding where new industries emerge and why new industries emerge where they do. Therefore there is a need to establish a more rigorous research agenda that will elucidate some of the more fundamental elements that contribute to the creation of new industries.

The evolutionary approach to economic geography (Boschma, Martin 2007, Boschma, Frenken 2006, Grabher 2009) draws strongly on evolutionary economics (Nelson, Winter 1982) and builds on the idea of path-dependent economic development (Arthur 1994, David 1985 etc. in, Martin, Sunley 2010, Martin, Sunley 2006). Although it may be argued that the influence of evolutionary economics in economic geography is new and untested (Maskell 2001), this approach has generated a series of new questions about regional economic development and the geographical context of industrial dynamics. The evolutionary turn in economic geography has thus stimulated questions regarding the origin and evolution of spatial economic phenomenon, such as clusters (Braunerhjelm, Feldman 2006, Menzel, Henn et al. 2010, Menzel, Fornahl 2010, Martin, Sunley 2011), and as in this paper, the spatial emergence of new industries.

This paper proceeds as follows: first, it is important to define the concepts of emerging industry and emerging technology and the often-intertwined relationship between them. Second, I highlight some of the most common approaches to studies of emerging industries in the field of economic geography and discuss their weaknesses in explaining the spatial emergence of new industries. Third, I include a section on the different evolutionary approaches of spatial emergence of new industries that have emerged in economic geography over the past three decades. Finally, I discuss where this development leaves us today in understanding the spatial origin of new industries and I highlight a research agenda for future studies.

Conceptual framing

Emerging technology

Industries and technologies are concepts that are closely related and yet differ substantially. Technology has been defined by Dosi (1984, p. 14) as “a set of pieces of knowledge, both directly ‘practical’ (...) and ‘theoretical’ (...), know-how, methods, procedures, experience of successes and failures and also, of course, physical devices and equipment.”

This understanding of technology is therefore not limited to the physical device Arthur (2009, p. 28) calls “a mean to fulfil a human purpose” but also encompasses disembodied accumulated competences and expertise of the state-of-the-art of the technology.

Engineers and scientists draw on this body of knowledge when solving the technical issues that lead to new innovations.

A crude distinction is often made between incremental and radical technological change (Garcia, Calantone 2002). Incremental innovations[2] occur continuously and are cumulative within technological trajectories (Nelson, Winter 1982, Freeman 1994, Dosi, Orsenigo 1988). Radical innovations, on the other hand, often lay the groundwork for totally new products or processes, generating paradigmatic changes (Dosi 1982, Dosi, Freeman et al. 1988). Radical innovations are of a discontinuous nature and may spur the emergence of new industries that have the potential to disrupt incumbent firms and industries.

Theories of evolutionary economics teach us that technological change is the core driver of economic development (Nelson, Winter 1982, Schumpeter 1934). The conditions under which technological change takes place vary depending on the nature of technological change; whether incremental or radical. It is generally acknowledged within the evolutionary paradigm that firms advance technologically through a process of search and selection driven by a search for new profit and new markets (Nelson, Winter 1982, Dosi 1988). This process is also observed for firms building on emerging technological paradigms; however, radical innovations distinguish itself from incremental innovation because search and selection processes occur in the context of a general "*weakness of market mechanisms*" (Dosi 1982, p. 155). By this, Dosi emphasises a fundamental difference in drivers between incremental innovation, induced by market mechanisms, and radical innovations being relatively autonomous from short-run adjustments to the economic system (e.g., changes in costs, prices, market shares etc) (Dosi 1982). Instead, the selection environment for radical technological change is determined by other factors, such as the notional opportunities provided by scientific progress, underlying economic factors, such as feasibility, marketability and profitability, and different types and sources of institutional influence (Dosi 1984). Moreover, the emerging phase rely heavily on experimental learning processes, which results in accumulation of scientific and applied knowledge in firms, universities, and research institutes. This accumulation means that the presence of risk-taking actors, who are willing and able to implement and exploit an emerging technology, is crucial for the development of new industries (Dosi 1982).

In reality, a complex set of variables develops interdependently under the influence of history and the nature of the given technology. For instance, circumstances that may trigger the emergence of one particular technology may not have a similar influence on other technologies. This concept can be illustrated by drawing a parallel between Dosi's study on the emergence of the semiconductor industry and the hydrogen and fuel cell technology in the 1950s and 1960s. Dosi (1984, p. 71) summarised the institutional

[2] In the following section, I mainly consider innovation as technological change, although innovation is a much broader concept that also includes organisational changes, new business models and services; however, all of these innovation types are strongly connected, and the emergence of radical technological changes often brings about all types of innovations, including product, processes, organisational, and service.

influence on the semiconductor industry as follows: "...institutional intervention (mainly military and space agencies) performed in the USA a powerful focusing role which directed the accumulation of knowledge and expertise and helped the emergence of precise technological trajectories."

Hydrogen and fuel cell technology received similar interest from NASA's space programmes in the 1950s and 1960s, but this *intervention*[3] did not bring about a large commercial breakthrough for fuel cell technology. The opportunity conditions (Malerba, Orsenigo 2000) for fuel cells were too low, and the scientific knowledge base may have been too immature to make fuel cells competitive with incumbent alternatives, e.g., the internal combustion engine, stationary power stations, or batteries. Institutional intervention is contextual, and its impact depends on the emerging technology and how it interacts with the other variables of scientific progress and the technology's feasibility, marketability and profitability.

The perspective is different for fuel cell technology today. Major scientific progress has been achieved in such knowledge fields as material science, chemistry, and nanotechnology, which form part of the current fuel cell knowledge base. This development has enabled a much wider breadth of notional possibilities to be provided by science within the emerging paradigm, enhancing the feasibility of the technology and thus of the opportunity conditions. Also, the institutional influence has changed, thereby resulting in a greater need for alternatives to incumbent energy technologies. This shift has increased the potential marketability and profitability of fuel cell technology. Developments, however, are still dependent on the presence of risk-taking actors who are willing and able to engage in the emerging fuel cell technology.

Emerging industry

As has become evident in the previous section, technology and industry are strongly connected in the evolutionary economic understanding of technological change. According to Essletzbichler and Winther (1999), an emerging technology is defined by purposeful organisations that seek to exploit its economic potential. The early risk-taking actors who explore and exploit a new technological paradigm's possibilities are defined in this thesis as an emerging industry; however, a number of issues related to the definition of emerging industry are discussed in this section.

In industrial organisation economics, an industry is usually defined as a group of firms that produce closely substitutable products to a market (Porter 1980, Forbes, Kirsch 2010). This definition has been criticised for a number of shortcomings. First, the definition does not include the dynamically changing network of horizontally and vertically related firms that often share common competences (Bettis 1998), and it disregards other potential competitors that may produce non-substitutable products (Sampler 1998). In emerging industry, however, this definition's major shortcoming is that an analytical focus on

[3] While the military did not pay much attention to fuel cell development in the West at this time, in Soviet Union the military engaged in developing fuel cell systems for submarines.

products and firms are of little use in understanding innovation (Abernathy, Utterback 1978), as the products do not exist yet, and firms are not the only actors involved in this early process.

Porter's (1980) acknowledge the controversy related to defining industries based on products in practice. For instance, in the case of the emerging fuel cell industry there are several different types of fuel cells[4]. Each of these has specific characteristics that make it particularly suitable for a different end-product application, one could argue that these products cannot be categorised in a single industry. As, however, the different types of fuel cells are largely built on the same scientific principle (and hence on the same knowledge base), fuel cell technology can therefore be perceived as a unifying technology group for all types of fuel cells. This categorisation is in line with Bettis's (1998, p. 359) alternative definition of an industry as "business units with similar capabilities". Consequently, the term 'emerging fuel cell industry' refers to a group of firms that base their businesses on fuel cell technology, regardless of the specific type of fuel cell.

Another definitional puzzle is related to the interface between traditional industry boundaries and emerging radical technological change. In such cases, the new activities related to developing the emerging technology become the point of exchange (Munir, Phillips 2002), and the contour of a new industry emerges, consisting of newcomers and incumbents. Munir and Philips (2002) introduce the concept of an 'activity network' to comprehend this type of competitive environment; however, the meaning of the term 'activity network' is too generic and thus too imprecise. The concept of 'emerging industry' expresses both that the key actors are firms and that the competitive parameters are somewhat different from mature industries. The latter term is consequently preferred here.

In Abernathy and Utterback's (1978) seminal work, the emerging industry is characterised by a 'fluid pattern of product changes' with high levels of diversity and uncertainty. The fluid phase is characterised by *extraordinarily high* levels of uncertainty in the direction of search, expectations for the technology, identification of main players and the strategic orientation in approaching markets (Dosi 1988, Utterback 1996). The length of the emergent phase, during which the company must survive with little or no sale in the market, is uncertain and is highly unpredictable *(Rogers 1995, Fagerberg 2005)*.

A final issue that is key to understanding 'emerging industry' is that the term in itself implicitly indicates development towards a full-grown mature industry; however, this growth is far from given. An emerging industry may never grow into a mature industry. This uncertainty is the risk early actors take on when entering a new technology area. Again, exemplified by the emerging fuel cell industry, this risk is very real. In particular, fuel cell technology's dependence on hydrogen technology has raised questions about the

[4] Fuel cells are categorized based on the type of electrolyte by which they function. For example, a solid oxide fuel cell (SOFC), the electrolyte is solid and made of ceramic. In a 'proton exchange membrane fuel cell' (PEMFC), also known as the polymer electrolyte membrane fuel cell, the electrolyte is made of polymers.

feasibility of a ‘hydrogen economy’ and hence about the importance of fuel cell technology. The major concerns are related to the inefficient production of hydrogen from renewable energy sources and the difficulties of storing hydrogen under high pressure. Nevertheless, the emerging fuel cell industry still attracts immense interest from industry actors and research communities that are optimistic about the technology’s potential.

Economic geography and studies of industry emergence

The temporal scope of industry emergence

As Abernathy and Utterback (1978) pointed out, emerging industries are difficult to study because they are challenging to identify and track until after their products appear on the market. This hindrance is associated with a lack of adequate data. For example, industrial classification schemes (e.g., SIC, NACE), which have been developed based on existing industry groupings, are problematic in studies of emerging industries.

It has recently been argued that scholars tend to stop asking questions about phenomena that are hard to study empirically, such as the emergence of industries (Forbes and Kirsch 2011). This aversion may also be why industry emergence has received so little attention in the field of economic geography; however, the reason may also be found in the temporal scope of the theories used in most industry studies within economic geography. Thus, there seems to be a blind spot in the field of economic geography, as well as in many other disciplines (Forbes, Kirsch 2010), regarding asking questions about the emergence of new industries.

Forbes and Kirsch (2010) illustrate how different types of studies may be categorised according to their temporal scope in relation to two time points: ‘industry founding’ and ‘the end of the emergent stage’ (see Figure 1). These authors’ main point is that most studies of emerging industries fall within Interval A, which begins with the emergent period and extends through later periods. Forbes and Kirsch claim that fewer studies focus on the remaining intervals, such as Interval B, which focuses on the emergent period, Interval C, in which focus is on the emergent periods, as well as preceding periods, and Interval D, which extends through all three periods.

This bias can be illustrated by Gort and Klepper’s (1982) use of the industry life cycle (ILC), in which they distinguish between two steps in product innovation that characterise emerging industry. The two steps are “the technical development of a new product and the introduction of the new product into the market” (Gort, Klepper 1982, p. 630). Although the time prior to market introduction is often recognised in ILC-studies, this period is almost just as often neglected in the actual analysis, as in the study by Gort and Klepper (1982, p. 630): “Our analysis begins with the second step when the new product is introduced into the market.”

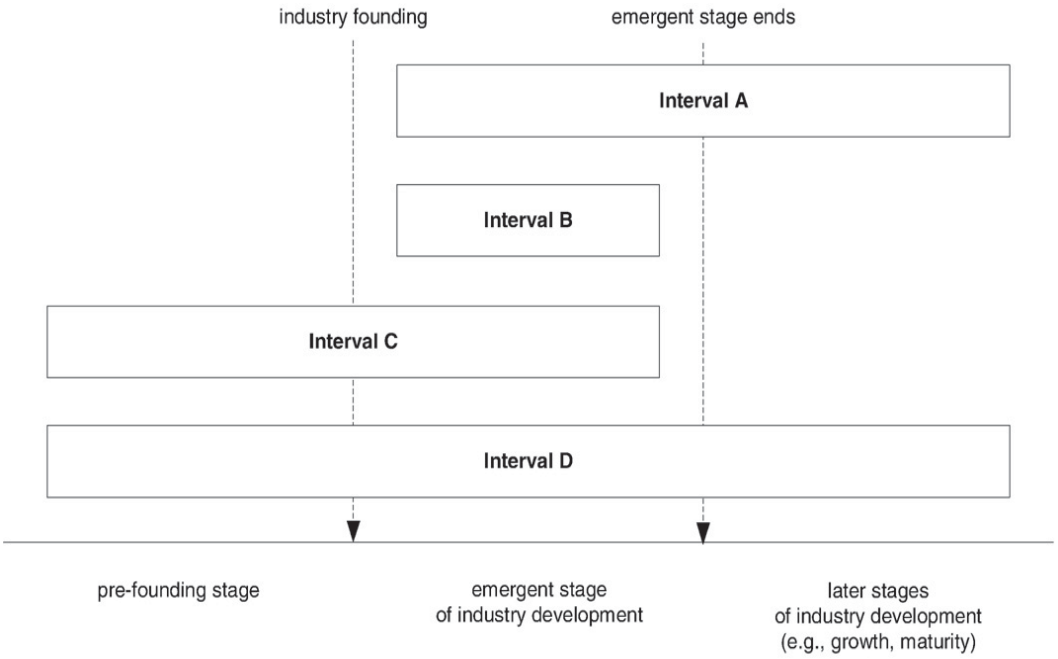

Figure 1: Alternative temporal intervals associated with theories of industry emergence, (Forbes, Kirsch 2010)

Additionally, there has been a notable lack of attention in economic geography to periods that precede the conventional industry life cycle, or in terms of evolutionary economics: the period during which the emerging technological paradigm is developed 'under a general weakness of market mechanisms'. In the following section, I discuss this tendency more thoroughly.

A lack of attention towards industry emergence

Most of the economic geography literature focuses on localised learning and agglomeration externalities framed by concepts such as industrial districts, clusters, innovative milieu, and regional innovation systems (Asheim, Smith et al. 2011). Core questions in industry emergence, such as 'How do industries come into being?' and 'To what extent is industry emergence embedded in geographical territories?' have received little attention in comparison. Only recently, with the *evolutionary turn* (Boschma, Martin 2007, Grabher 2009, Boschma, Frenken 2006) in economic geography, scholars have began to pay attention to the origin and early evolution of industries (Boschma, Lambooy 1999, Storper, Walker 1989) and particularly to the emergence of clusters (Braunerhjelm, Feldman 2006, Martin, Sunley 2011, Menzel, Henn et al. 2010).

Clearly, several different emerging industries have received attention in economic geography (see, e.g., Feldman, Lendel 2010, Feldman 2003, Dahl, Østergaard et al. 2010, Zucker, Darby et al. 1998, Zucker, Darby et al. 2007), but they have mostly been studied through the lens of clusters (Braunerhjelm, Feldman 2006, Menzel, Henn et al. 2010, Menzel, Fornahl 2010) or the 'industry life cycle' (see, e.g., Audretsch, Feldman 1996, Neffke, Henning et al. 2011). I will argue, however, that because of their inherent

temporal focus on industry development after the founding stage, both approaches face difficulties in grasping the essentials of how new industries come into being.

First, cluster studies clearly fall within Interval A in Figure 1, as the earliest firms to enter an emerging industry area would not qualify as clusters: geographical concentrations of firms from related industries that benefit from a common pool of skilled labour, specialised suppliers, and knowledge externalities (Porter 1990). Clusters are spatial economic phenomenona that are much more narrowly defined than industry and *appear* at a later time than the industry itself. Hence, industry emergence falls outside the analytical scope of cluster studies. Clusters may still be an essential component in the economic evolution of industries, but it is necessary to go beyond the concept of clusters in order to appreciate industry emergence in its geographical context.

The ILC perspective is another approach that has been employed in economic geography-studies of emerging industries, which also belongs to Interval A in Figure 1. The use of ILC in economic geography has, similar to its application in other fields (Forbes, Kirsch 2010), a tendency to focus on the part of early industry development that begins with commercialisation. Also, the pre-commercial phase, which tends to be both lengthy and costly, is often not included in such studies (e.g. Neffke, Henning et al. 2011, Audretsch, Feldman 1996).

From the ILC approach in economic geography, we learn often-stylised facts about what distinguishes the fluid phase of industry evolution from later and more mature stages. For example, the propensity of innovative activity to geographically cluster is higher at the early stage of the ILC (Audretsch, Feldman 1996), and young industries benefit more from Jacobs' externalities (Neffke, Henning et al. 2011, Henderson, Kuncoro et al. 1995). Such insights may be useful in understanding the conditions underlying emerging industries, but there are yet other underexposed aspects of industry emergence belonging to what Forbes and Kirsch (2010) have termed the pre-founding stage of an industry. These aspects call for studies with a temporal scope that extends backwards to include some period of time prior to what we generally perceive as the boundaries of an emerging industry.

Such studies should focus on the origin and early evolution of emerging industries (Interval C in Figure 1). Where the temporal and spatial scope comprise what we could call a pre-cluster stage, i.e., the location where an industry first appears but does not necessarily develop into dominant places characterised by localised increasing returns effects. This growth may occur eventually, but a nascent industry may also wither away or relocate to more fertile ground. In both cases, there is a theoretical interest in understanding the early processes of industry emergence or industry failure.

An evolutionary understanding of spatial industry emergence

The evolutionary economic paradigm offers an explanatory perspective that includes the emergent phase of industry development. This integration of evolutionary economics into economic geography has stimulated questions about the spatial emergence of economic phenomena (Boschma, Lambooy 1999, Storper, Walker 1989), as well as about other

related matters, such as the role of the firm in economic geography (Maskell 2001), regional resilience (Hassink 2010), and cluster life cycles (e.g. Menzel, Fornahl 2010, Ter Wal, Boschma 2011). This section presents two models that build on an evolutionary understanding of the spatial emergence of new industries: first, the geographical application of path dependence, as introduced by Arthur (1994), and second, the model of windows of locational opportunities (Boschma, Lambooy 1999, Storper, Walker 1989). The major assumptions of the models are discussed in relation to other perspectives on path dependence in the emerging field of evolutionary economic geography (Martin, Sunley 2006, Martin 2010). Finally, the gap in the literature is outlined.

Path dependence

A concept that has played a central role for the evolutionary turn in economic geography is path dependence (Arthur 1994, David 1985), which is key to understanding technological and industrial development in evolutionary economics. According to Martin and Sunley (2006, p. 399) "a path dependent process or system is one whose outcome evolves as a consequence of the process's or system's own history." Path dependence is born of the view that the opportunities of today are formed by decisions made in the past and that the technology or system exhibits strong features of irreversibility. This concept also recognises that even small events or decisions made in the past can have a decisive impact on how a system or a technology develops and may consequently affect the range of later opportunities (Arthur 1994). Hence, path dependence is closely related to the concept of lock-in, which describes a situation in which a development process is locked, or constrained, to a given technological paradigm because of decisions made in the past.

Arthur (1994) has applied the concept of path dependence on regional economic development by simulating three types of locational processes. Arthur's first model builds on the deterministic assumptions of traditional economic geography in which the geographical distribution of resources is the only factor determining an industry's location. In this model, a firm's choice of location does not affect other firms' choices of location.

The second model is framed as a 'pure chance' model in which the only mechanism driving regional formation of an industry is spinoffs. It is assumed that new firms stay in their parent location and that every firm, including the new spinoffs, has a certain probability of spinning off a new firm. The result is highly unpredictable and shows a high degree of path dependence with industry location; every time the three-region simulation model is run, the location pattern changes. Arthur concludes that *history* is the determining factor for industry location. In this model, "history" is the initial conditions in the region that originates the spin off firms, which is the number of initial firms.

Arthur's third model builds on the assumption of 'location under agglomeration economies'. This term means that the more firms that end up in one location 'by chance', the higher the probability that the next firm will be found in the same region. This phenomenon results in a concentration of firms in one region that outperforms other locations. The choice of favoured location for later firms depends on the initial location

pattern of the early firms, which, according to Arthur's model, is determined equally by chance and by the attractiveness of the region that the first firms enter. Hence, the fundamental principle in Arthur's two latter models is that 'small events' at different points in history decide the regional formation of industry. Thus, the location of new industries becomes unpredictable (Arthur 1994).

Arthur's ascription of so much explanatory power to random, small events in a highly simplistic simulation of economic development has drawn criticism (see, e.g., Martin 2010, Boschma 2007). This criticism can be summarised in three points (Boschma 2007). First, Arthur's models completely neglect evolutionary industrial dynamics; for example, he does not account for the fact that firms are heterogeneous in terms of size, resources, and strategic goals at different points in time. Second, the models do not take into account possible negative lock-in in the regional economy, which may manifest itself in higher costs, inadequate knowledge resources, and institutional inertia that may hinder future regional economic development (Hassink 2010). Third, the models do not incorporate an understanding of geographical, contextual factors that may influence the spatial emergence of new industries (Martin, Sunley 2006, Boschma 2007). In other words, Arthur's models provide a *one-way* account for how new industries shape regional path-dependent development, but they fail to integrate feedback mechanisms from pre-existing regional economic structures.

Window of locational opportunity

Another branch of the literature that to some extent assumes that new industries form space, and not the other way around, is the window of locational opportunity (WLO) (Storper, Walker 1989, Scott, Storper 1987). The WLO model is an attempt to understand why new industries locate in new places and cause 'old industrial regions' to decline. Storper and Walker argue (1989) that because the input requirements of a new industry in terms of labour skills, materials, machines, parts and equipment is rarely met by pre-existing locational conditions, firms have *locational freedom* - the opportunity to choose their own locations. The period during which firms experience locational freedom is termed the 'window of locational opportunity'.

Once a firm has established itself in a given region, it is tied to its location by fixed investments, established relationships to other actors and training of its employees (Storper, Walker 1989). Hence, the WLO model claims that the initial location of a firm, whether it is caused by a short-term strategic choice or an accidental event, structures the spatial landscape. The more firms that choose a specific location and the more these firms create their own unique locational conditions by interacting with their local surroundings, the narrower the window for new locations becomes.

The WLO approach has been extended and refined by Boschma and Lambooy (Boschma, Lambooy 1999) Boschma and van der Knaap (1997) and again by Boschma (2007). In these modifications, evolutionary concepts, such as chance, selection environment, and increasing returns (agglomeration economies), become more pronounced. The selection environment is excluded because of the disparity between the requirements of the radical

new technology and the production structure of regions; chance, on the other hand, plays a significant role, albeit not as much as in Arthur's model, and increasing returns play a role after the industry has emerged and the window starts to close.

The principal expansions on the WLO model place a greater emphasis on possible generic parameters, such as general knowledge, skills, suppliers of services, and urbanisation economies, which may influence the location of new industries. Boschma and Lambooy (1999) distinguish between generic and specific factors. Specific factors (i.e., specialised inputs) are not considered important because of the wide gap between the requirements of an emerging industry and the resources of a region at a given time. Furthermore, generic resources are typically present in a large number of regions and consequently cannot decide the emergence of new industries.

As a consequence of poor explanatory power of regional resources, both the early and later version of the WLO model assign greater explanatory power to human agency (Boschma, Lambooy 1999, Storper, Walker 1989), arguing that the firm creates its own locational conditions and that this process depends on the creative ability of the firm to turn generic resources into specific assets (Boschma, Lambooy 1999). This ability also includes encouraging the development of specialised educational and other supportive institutions (Storper, Walker 1989). The more successful human agents are in creating specific knowledge assets from generic resources, the more attractive the region becomes to later entries. Hence, as the window narrows, the early evolution of the industry becomes more and more driven by localisation economies (increasing returns).

Alternative evolutionary perspectives on spatial emergence of industry

The WLO model is appealing because it accounts for the idea that regional economic development is neither deterministic nor static. Relatively less developed regions may generate new industries that cause the region to leapfrog old industrial centres; however, the fundamental assumptions of this model concerning relative spatial independence and the role of chance events have been criticised.

The two assumptions regarding locational freedom and chance are highly related, as is seen with the introduction of generic resources as a possible explanatory factor for the localisation of emerging industries. In contrast to Arthur's model, generic resources constrain the role of chance because firms do not develop entirely independently of local resources. As Boschma frames it,

> "...the WLO model enables us to determine empirically the extent to which chance influences the spatial outcome: the more potential locations can be identified empirically, the lower the degree of predictability, and the more open the windows of locational opportunity are" (Boschma 2007, p. 45).

Accordingly, chance events become important when the generic resources are plentiful and located in multiple regions. Conversely, when relevant generic resources are scarce (only present in few locations), the role of chance in the locational process of emerging industries is much smaller.

Nevertheless, the WLO model has been criticised for the relatively large share of the explanatory power it ascribes to accidental events and for its inadequate emphasis on contextual and causal factors (Martin, Sunley 2006). Martin and Sunley (2006) and Martin (2010) propose a different interpretation of path dependence that allows for stronger interdependence between paths in regional economic development:

> "The emergence of a new local industry may not be due to 'chance' or 'historical accident,' but may be stimulated or enabled—at least in part—by the preexisting resources, competences, skills, and experiences that have been inherited from previous local paths and patterns of economic development." (Martin 2010 p. 20)

The path-dependent process in Martin's (2010) interpretation thus becomes a path-enabling process in which new paths are made possible through entrepreneurial activities that build on localised resources. According to Martin and Sunley (2006), new industry development shape the economic landscape, but the place where a new industry emerges strongly influences the path-dependent development of an industry. Martin and Sunley argue that because many mechanisms underlying path dependence have an inherent local dimension, the process of industry emergence is place-dependent. Consequently, Martin and Sunley (2006) and Martin (2010) advocate for a model wherein localised knowledge resources play a greater role than in the WLO model, reducing the role of chance as a driver of industry emergence.

The conceptualisation of the spatial emergence of new industries has, thus, caused a dispute in the emerging field of evolutionary economic geography. On the one hand, the WLO model argues that firms in newly emerging industries experience relative locational freedom and can choose their location among a number of regions with generic resources. On the other hand, a reinterpretation of path dependence perceives a stronger interdependency between regional industrial paths. And it is argued that this interdependency is also seen in the emergence of industries.

Framed differently, the dispute in the emerging field of evolutionary economic geography hinges on the degree to which cumulative knowledge influences the creation of new technological paradigms (Dosi 1988) and to what extent this process is localised or occurs relatively independent of the spatial industrial structure. The more explanatory power is ascribed to regional knowledge dynamics and human agency, the less importance need to be assigned to chance.

New strand in economic geography: an evolutionary take on the emergence of industries

Recent research has assessed the importance of knowledge resources for regional economic development, including the development of new industrial paths. The main claim is that new industries tend to emerge in regions where the pre-existing regional knowledge base is related to the emerging industry. The key argument is that learning and knowledge transfers between actors, such as firms, universities and research institutes tend to be constrained by space (Audretsch, Feldman 1996). Thus, geographical proximity to

the source of knowledge is important for accessing the knowledge. However, Boschma (2005) argues that geographical proximity is neither a necessary nor a sufficient condition for the transfer of knowledge between actors. Other barriers that hinder knowledge transfer count cognitive, social, organisational and institutional distance. Consequently, in order for fruitful knowledge transfers to occur a balanced level of proximity need to be met and in addition the actors need absorptive capacity to understand and integrate the new knowledge (Cohen, Levinthal 1990).

A balanced level of for example, cognitive proximity means that two actors need to share similar knowledge to allow effective communication but not too much cognitive proximity to avoid cognitive lock-in (Nooteboom 2000). If two people know exactly the same there is nothing to learn from each other. Therefore it has been argued that a regional industrial structure should be characterised by a certain level of variety (Jacobs 1969), which makes knowledge transfer between different industries possible. However, it is only when the economic activities are related, that is cognitive proximate that knowledge sharing can be met (Boschma, Gianelle 2014).

The process of regional diversification based on pre-existing competences has been labelled regional branching (Boschma, Frenken 2011). It is proposed that the mechanisms inducing this process count firm diversification, entrepreneurial spin-offs and start-ups, labour mobility and networking, which all have a local bias. Research support that in some cases entrepreneurial spinoffs are the driving mechanisms (Klepper, Simons 2000, Boschma, Wenting 2007) and in other cases it has been shown that firm diversification play a key role (Tanner 2014). The role of labour mobility and networking activities for regional branching are on the other hand underexplored.

Empirical regularities on regional branching

Frenken et al. (2007) focus on the relationship between the industrial structure of a region and economic development. They argue that the more mutually technologically related a region's industrial base is the higher level of knowledge spillover, which will cause an increase in economic activities. Frenken et al. confirm that regions with high degree of 'related variety' in their economic activities support a higher degree of knowledge spillover, which, in turn, enables employment growth (Frenken, Van Oort et al. 2007). In this connection, employment growth can in itself indicate the emergence of new economic activities. Related variety thus, becomes a measure of the cognitive proximate relationship between industrial paths in a given region.

Other studies have focused on measuring 'technological relatedness' between industries over longer term. For instance, Neffke, Henning and Boschma (2011) examine the long-term structural changes of regional economies in Sweden and find that regions diversify in a relatively coherent path over time, confirming that the paths are interdependent. Accordingly, firms with competences technologically related to the industrial structure of a region are more likely to enter this region and firms who have technologically unrelated competences to a region's industrial portfolio are more likely to exit. It is argued that this path-dependent development is induced by spillover of localised knowledge, which is

enhanced by cognitive proximity between industrial paths in a given region (Boschma, Frenken 2011).

Similarly, there is increasing evidence that technological relatedness play a key role in the development of new industrial growth paths. Multiple case studies have demonstrated the linkages between pre-existing economic activities and the emergence of new industries. Klepper and Simons (2000) demonstrate that the television industry developed based on spinoffs coming from the radio industry and Boschma and Wenting (2007) show that the British automobile industry emerged based on spinoffs from the pre-existing bicycle producers.

Recent research supports the thesis of regional branching based on more systematic studies. For instance, Tanner (2011) demonstrates that regionally accumulated technological knowledge related to the fuel cell technology is significantly linked to the spatial emergence of the fuel cell industry in Europe. Other studies have shown similar results for nanotechnology (Colombelli, Krafft et al. 2012) and biotech (Boschma, Heimeriks et al. 2014).

However, Tanner (2014) has demonstrated that regional diversification is not only driven by the logic of technological relatedness. She shows how some regions diversify into the emerging industry of fuel cells because firms located in these regions apply the technology in their products without having technologically related competences to the new technology. This type of diversification occurs because of what has been called application or market relatedness. Although, there is a need for more studies to clarify the consequences of the different types of diversification patterns, it is interesting to think that regions can diversify into the same emerging industry by following multiple pathways.

Based on these empirical findings it can be argued that there appear three ways for regions to diversify into new industries: 1) a new industry may grow out of an old industry 2) a new industry may be the result of the recombination of competences coming from several industries (Boschma, Frenken 2011) and 3) an existing industry may apply emerging and/or generic technologies in their product portfolio which cause the emergence of a new industry (Tanner, 2014). In the first two examples, regional diversification occurs based on the logic of technological relatedness (Boschma & Frenken, 2011), i.e., the new activities build on the same scientific or engineering principles as preexisting activities. In the third example, regional diversification occurs based on the logic of market relatedness (Tanner, 2014). In such processes, firms do not take advantage of technologically related activities but base their diversification on their competences and relationship to the market in which the new technology is applied.

Consequently, the emerging literature on related variety and technological relatedness promises to be useful in understanding the process of regional diversification – also in the case of emerging industries! The above mentioned studies shed new light on how the emergence of new industries is linked to pre-existing economic activities and knowledge bases of regions. This strand of literature consequently contributes to resolving the dispute about: whether the emergence of new industries is a process characterised by chance and

locational freedom from pre-existing economic structure or whether pre-existing economic structures and regional knowledge bases influence the location of new and emerging industries. In consequence, these studies seek to place less explanatory power to chance and more to regional knowledge dynamics and human agency.

Directions for Future Research

The role of Institutions

Most of the above mentioned studies focus on the role of knowledge and learning in the process of developing new industries, which comes naturally given the key importance knowledge receives in explaining contemporary economic development (Lundvall, Borrás 1999, Lundvall, Johnson et al. 2002, Foray 2004). However, there are also other factors of spatial industry emergence, which are still underexposed and should be included in future studies. One obvious shortage is the lack of attention to the role of institutions.

Agarwal and Tripsas (2008) call for additional work on how industrial life cycle dynamics differ by geographic region. They draw our attention to the limited comparative research that has been done in examining life cycle patterns across countries or regions. One example is Chesbrough (1999) who demonstrates the differences between disk drive firms in Japan and the USA, respectively. Chesbrough (1999) ascribes the differences to institutional factors related to labour market, venture capital and buyer-supplier ties. Similarly, Murmann and Homburg (2001) show that patterns of industry evolution differ significantly across different national institutional settings.

Similarly it is reasonable to assume that the pre-commercialisation phase also differ across national or regional institutional settings. However, there is very little research that specifically looks at the role of institutions in the origin and early evolution of industries. This calls for comparative research of spatial processes of industry emergence. In particular there is a strong need to examine the role of institutions on variations of regional branching across regional economies.

In addition, what is still lacking is a more comprehensive understanding of regional path dependent development under different influences of macroeconomic development, such as recessionary shocks or prosperity, and cultural and institutional factors. These factors' impact on regional branching has not yet been taken into consideration in the relatively young literature on regional branching, although there are good reasons to include these.

The mechanisms of regional branching do not exist in a vacuum. Firm diversification and entrepreneurial spinoffs and start-ups are strongly influenced by the prevailing conditions of the society where they take place. For instance, macroeconomic trends and the institutional environments are believed to have great impact on the willingness for firms and individuals to bear the risk of entering new industrial areas (Schøtt 2010). Consequently it is likely that these conditions have great impact on the process of regional branching.

Multiple Pathways of Diversification

As the study of Tanner (2014) revealed, regions can diversify and develop new industries based on different set of logics. Some regions diversify driven by the mechanisms of firm diversification and entrepreneurial start-ups based on the logic of technological relatedness (i.e., building on the same scientific or engineering principle). Whereas other regions develop new industries based on the mechanisms of firm diversification based on the logic of market relatedness (i.e., when firms apply new/generic technologies in existing products). This finding calls for further studies on the logics of diversifications. First, are there other logics of related diversification besides technological relatedness and market relatedness? Second, are there certain mechanisms, such as firm diversification, start-up, networking and labour mobility that prevails one or the other logic of diversification? And third what implication does one or the other way of diversifying have on the preeixisting industrial structure of a region?

How Emerging Industries Shape the Economic Landscape

From an academic and not least from a policy perspective, it is potentially interesting to analyse the changes of the economic landscape an emerging industry may cause. In fact new industries may disrupt the economic landscape at two levels. First, there is the question related to the disruptive nature of emerging industries, which the literature on WLO was occupied with. When new industries take off in locations that differ from existing economic centres they bear the potential of creating new economic centres and existing centres face the risk of declining.

Second, at the level of regional economies is the question of how different patterns of industry evolution produce different types of geographies. Such early indications may give policy makers a tool to support industry-building in the best possible way. For instance, there may be different strategies depending on whether incumbent MNEs or smaller spinoff firms characterise a new industry in a region. Research on this issue may improve regional innovation policies. These policies today are dominated by the idea of creating clusters, which sometimes seem to have little basis in the regional industrial structure (Sölvell, Lindqvist et al. 2003).

Markusen's (1996) significant contribution to the industrial district literature is a possible theoretical framework that could shed light on the formation of new geographies based on spatial industry emergence. She distinguishes between hub-and-spoke districts, state-anchored districts and satellite districts besides the familiar definitions of industrial and Marshallian districts. It can be argued that if regional branching occurs in a hub-and-spoke district, where the regional economy depends on the large firm's strategy, implications for the regional economy are different than if regional branching occurs in a Marshallian district, characterized by smaller firms.

Consequently, future research should try and clarify the consequences of regional branching processes in different types of regional economies. The objective of such research should also be to develop recommendations on policy making, in order to improve regions adaptability to emerging industries.

More on the type and size of actors

Another issue which has not been investigated in relation to emerging industries is the role different type of actors play in regional branching processes. There is a tendency to study this phenomenon at a much aggregated level that does not take into account the different type of actors (small firms, multinational enterprises, universities and research institutes etc.) and their role in emerging industries at the regional level. As mentioned above different types of actors may shape regional development differently.

It can also have an impact on the geography of knowledge flows (local vs. global). For example, Tanner (2014) show that MNE play an important role in some regional branching processes in the case of fuel cell technology, and that universities and research institutes play a key role in other regions.

However, the fact that MNEs play a dominating role in some regional settings casts doubt on the innate localised nature of innovation in the early stage of industry life cycles (Audretsch, Feldman 1996) as well as in pre-commercialisation phase. In relation to regional branching processes, it is still underexposed what role MNEs play early in industry evolution and which implications it has for the localised nature of emerging industries. MNEs, as their name indicates, have an innate capability to act in multiple locations across national and regional borders. That means that if MNEs enter an emerging industry, their inherited routine-based behaviour of acting globally through a net of subsidiaries is passed on to the knowledge-producing activities within the emerging industry.

For example, when Daimler entered the fuel cell industry, Daimler taps into knowledge resources located in the Canadian fuel cell industry in Vancouver, *embodies* the knowledge in fuel cell stacks, and transfers this embodied tacit knowledge to its fuel cell system development facility in Nabern, near Stuttgart. The Daimler example is a clear indication of globalized knowledge flows which ought to receive more attention in economic geography.

To investigate the localised character of knowledge flows in the very early stages of industry emergence, primary data sources seem to be the best empirical instrument. Examples include survey data on regional, national, and international knowledge flows, such as labour flows, patent licensing, acquisitions and mergers, such as that used by Gertler and Levitte (2005) in their analysis of ‘local nodes in global networks’. Such studies would also increase our understanding of local vs. global knowledge input in regional branching processes into contemporaneous emerging industries.

Conclusion

In this paper I have argued for a stronger focus on the origin and early evolution of industries in the field of economic geography. I have outlined the development in the evolutionary turn in economic geography and appraised the recent development, which seems to come up with answers that contribute to a clearer understanding of why new industries emerge where they do. Finally, I have outlined the many issues which require

continuous scholarly attention in order to increase our understanding of the dynamics and conditions for emerging industries in regional economies.

From a broader perspective, research on related variety (Jacobs 1969) and 'technological relatedness' (Boschma, Frenken 2011), of which this research is a part, has contributed to a dynamic understanding of regional economic development. As such, the evolutionary turn in economic geography has contributed to an enhanced understanding of regional growth paths (Frenken, Van Oort et al. 2007, Bishop, Gripaios 2010), the role of technological relatedness in agglomeration externalities (Neffke, Henning et al. 2011, Neffke, Henning et al. 2011), related variety in trade linkages (Boschma, Iammarino 2009), and latest with an improved understanding of the spatial emergence of new industries through technologically related knowledge spillover. This result is encouraging for the emerging field of evolutionary economic geography.

The evolutionary research path in economic geography seems promising and should continue with further investigations of the complex nature of knowledge dynamics, human agency, and institutional influence at the regional level. In spite of a promising path more studies are necessary to understand how regions may renew themselves and escape becoming locked-in to old industrial paths. Such research will further illuminate why particular technologies have led to the creation of industries in particular locations. And expectedly, such research will increase the academic support of regions' efforts in developing regional advantages around an emerging industry.

References

ABERNATHY, W.J. and UTTERBACK, J.M., 1978. Patterns of industrial innovation. *Technology review,* **80**(7), pp. 40-47.

AGARWAL, R. and TRIPSAS, M., 2008. Technology and industry evolution. In: S. SHANE, ed, *Handbook of Technology and Innovation Management.* John Wiley & Sons, pp. 3.

ARTHUR, W.B., 2009. *The nature of technology: What it is and how it evolves.* New York: Free Press.

ARTHUR, W.B., 1994. *Increasing returns and path dependence in the economy.* USA: University of Michigan Press.

ASHEIM, B.T., SMITH, H.L. and OUGHTON, C., 2011. Regional Innovation Systems: Theory, Empirics and Policy. *Regional Studies,* **45**(7), pp. 875-891.

AUDRETSCH, D.B. and FELDMAN, M.P., 1996. Innovative clusters and the industry life cycle. *Review of Industrial Organization,* **11**(2), pp. 253-273.

AUDRETSCH, D.B. and FELDMAN, M.P., 1996. R&D Spillovers and the Geography of Innovation and Production. *The American Economic Review,* **86**(3), pp. 630-640.

BETTIS, R.A., 1998. Commentary on 'redefining industry structure for the information age'by JL Sampler. *Strategic Management Journal,* **19**(4), pp. 357-361.

BISHOP, P. and GRIPAIOS, P., 2010. Spatial externalities, relatedness and sector employment growth in Great Britain. *Regional Studies,* **44**(4), pp. 443-454.

BOSCHMA, R.A., 2007. Path creation, path dependence and regional development. In: J. SIMMIE and J. CARPENTER, eds, *Path Dependence and the Evolution of City Regional Development, Chapter 3, Working Paper Series No. 197.* Oxford: Oxford: Oxford Brookes University, pp. 40-55.

BOSCHMA, R.A., 2005. Proximity and innovation: a critical assessment. *Regional Studies,* **39**(1), pp. 61-74.

BOSCHMA, R.A. and FRENKEN, K., 2011. Technological relatedness and regional branching. In: H. BATHELT, M.P. FELDMAN and D.F. KOGLER, eds, *Dynamic Geographies of Knowledge Creation and Innovation.* London: Routledge, Taylor and Francis, .

BOSCHMA, R.A. and FRENKEN, K., 2011. Technological relatedness, related variety and economic geography. In: P. COOKE, B. ASHEIM, R. BOSCHMA, R. MARTIN, D. SCHWARTZ and F. TODTLING, eds, *The Handbook on Regional Innovation and Growth.* Cheltenham: Edward Elgar., .

BOSCHMA, R.A. and FRENKEN, K., 2006. Why is economic geography not an evolutionary science? Towards an evolutionary economic geography. *Journal of Economic Geography,* **6**(3), pp. 273-302.

BOSCHMA, R.A. and IAMMARINO, S., 2009. Related variety, trade linkages, and regional growth in Italy. *Economic Geography,* **85**(3), pp. 289-311.

BOSCHMA, R.A. and LAMBOOY, J.G., 1999. Evolutionary economics and economic geography. *Journal of Evolutionary Economics,* **9**(4), pp. 411-429.

BOSCHMA, R.A. and MARTIN, R., 2007. Constructing an evolutionary economic geography. *Journal of Economic Geography,* **7**(5), pp. 537-548.

BOSCHMA, R.A. and WENTING, R., 2007. The spatial evolution of the British automobile industry: Does location matter? *Industrial and Corporate Change,* **16**(2), pp. 213-238.

BOSCHMA, R.A. and VAN DER KNAAP, B., 1997. New technology and windows of locational opportunity: indeterminacy, creativity and chance. In: J. REIJNDERS, ed, *Economics and Evolution.* Cheltenham UK: Edward Elgar, pp. 171-202.

BOSCHMA, R. and GIANELLE, C., 2014. *Regional Branching and Smart Specialisation Policy.* 06/2014. European Commission: Institute for Prospective and Technological Studies, Joint Research Centre.

BOSCHMA, R., HEIMERIKS, G. and BALLAND, P., 2014. Scientific knowledge dynamics and relatedness in biotech cities. *Research Policy,* **43**(1), pp. 107-114.

BRAUNERHJELM, P. and FELDMAN, M.P., 2006. *Cluster genesis: technology-based industrial development.* New York, USA: Oxford University Press,.

CHESBROUGH, H.W., 1999. The organizational impact of technological change: a comparative theory of national institutional factors. *Industrial and Corporate Change,* **8**(3), pp. 447-485.

COHEN, W.M. and LEVINTHAL, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly,* , pp. 128-152.

COLOMBELLI, A., KRAFFT, J. and QUATRARO, F., 2012. *The emergence of new technology-based sectors at the regional level: a proximity-based analysis of nanotechnology.* Utrecht University, Section of Economic Geography: Papers in Evolutionary Economic Geography, no. 12.11.

DAHL, M.S., ØSTERGAARD, C.R. and DALUM, B., 2010. Emergence of regional clusters: the role of spinoffs in the early growth process. In: R. BOSCHMA and R. MARTIN, eds, *The handbook of evolutionary economic geography.* Cheltenham UK: Edward Elgar, pp. 205-220.

DAVID, P.A., 1985. Clio and the economics of QWERTY. *American Economic Review,* **75**, pp. 332-337.

DAY, G.S., SCHOEMAKER, P.J.H. and GUNTHER, R.E., 2000. *Wharton on managing emerging technologies.* John Wiley & Sons Inc.

DOSI, G., 1988. The nature of the innovative process. In: G. DOSI, C. FREEMAN, R. NELSON, G. SILVERBERG and L. SOETE, eds, *Technical change and economic theory.* London: Pinter Publishers, pp. 221-238.

DOSI, G., 1988. Sources, procedures, and microeconomic effects of innovation. *Journal of economic literature,* , pp. 1120-1171.

DOSI, G., 1984. *Technical change and industrial transformation.* London, UK: The Mackmillan Press Ltd.

DOSI, G., 1982. Technological paradigms and technological trajectories:: A suggested interpretation of the determinants and directions of technical change. *Research policy,* **11**(3), pp. 147-162.

DOSI, G., FREEMAN, C., NELSON, R., SILVERBERG, G. and SOETE, L., 1988. Technical change and economic theory. *LEM Book Series,* .

DOSI, G. and ORSENIGO, L., 1988. Coordination and transformation: an overview of structures, behaviours and change in evolutionary environments. In: G. DOSI, C. FREEMAN, R.R. NELSON, G. SILVERBERG and L. SOETE, eds, *Technical Change and Economic Theory.* London: Pinter Publishers, pp. 13-37.

ESSLETZBICHLER, J. and WINTHER, L., 1999. Regional technological change and path dependency in the Danish food processing industry. *Geografiska Annaler: Series B, Human Geography,* **81**(3), pp. 179-196.

FAGERBERG, J., 2005. Innovation: A Guide to the Literature. In: J. FAGERBERG, D.C. MOWERY and R.R. NELSON, eds, *The Oxford Handbook of Innovation.* Oxford: Oxford University Press, pp. 1-26.

FELDMAN, M.P., 2003. The locational dynamics of the US biotech industry: knowledge externalities and the anchor hypothesis. *Industry and Innovation,* **10**(3), pp. 311-329.

FELDMAN, M.P. and LENDEL, I., 2010. Under the lens: The geography of optical science as an emerging industry. *Economic Geography,* **86**(2), pp. 147-171.

FORAY, D., 2004. *Economics of knowledge.* Cambridge, MA.: the MIT Press.

FORBES, D.P. and KIRSCH, D.A., 2010. The study of emerging industries: Recognizing and responding to some central problems. *Journal of Business Venturing,* **26**(5), pp. 589-602.

FREEMAN, C., 1994. The economics of technical change. *Cambridge journal of economics*, **18**(5), pp. 463-514.

FRENKEN, K., VAN OORT, F. and VERBURG, T., 2007. Related variety, unrelated variety and regional economic growth. *Regional Studies*, **41**(5), pp. 685-697.

GARCIA, R. and CALANTONE, R., 2002. A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management*, **19**(2), pp. 110-132.

GERTLER, M.S. and LEVITTE, Y.M., 2005. Local nodes in global networks: the geography of knowledge flows in biotechnology innovation. *Articles & Chapters*, , pp. http://digitalcommons.ilr.cornell.edu/articles/122.

GORT, M. and KLEPPER, S., 1982. Time paths in the diffusion of product innovations. *The Economic Journal*, **92**(367), pp. 630-653.

GRABHER, G., 2009. Yet another turn? The evolutionary project in economic geography. *Economic Geography*, **85**(2), pp. 119-127.

HASSINK, R., 2010. Regional resilience: a promising concept to explain differences in regional economic adaptability? *Cambridge Journal of Regions, Economy and Society*, **3**(1), pp. 45-58.

HENDERSON, V., KUNCORO, A. and TURNER, M., 1995. Industrial development in cities. *Journal of Political Economy*, **103**(5), pp. 1067-1090.

JACOBS, J., 1969. *The economy of cities.* Vintage Books.

JENSEN, M.J., 2000-last update, The Technocultural Crucible. Available: http://www.ekac.org/kulturnyt.html2011].

KENNEY, M. and VON BURG, U., 2001. Paths and regions: the creation and growth of Silicon Valley. In: R. GARUD and P. KARNØE, eds, *Path Dependence and Creation.* London, UK: Lawrence Erlbaum Associates, pp. 127-148.

KLEPPER, S. and SIMONS, K.L., 2000. Dominance by birthright: entry of prior radio producers and competitive ramifications in the US television receiver industry. *Strategic Management Journal*, **21**(10-11), pp. 997-1016.

LUNDVALL, B.A. and BORRÁS, S., 1999. The globalising learning economy: Implications for innovation policy. *Office for Official Publications of the European Communities, Luxembourg*, , pp. 1–30.

LUNDVALL, B.Å, JOHNSON, B., ANDERSEN, E.S. and DALUM, B., 2002. National systems of production, innovation and competence building. *Research policy*, **31**(2), pp. 213-231.

MALERBA, F. and ORSENIGO, L., 2000. Knowledge, innovative activities and industrial evolution. *Industrial and corporate change,* **9**(2), pp. 289-314.

MARKUSEN, A., 1996. Sticky places in slippery space: a typology of industrial districts. *Economic geography,* **72**(3), pp. 293-313.

MARTIN, R., 2010. Roepke Lecture in Economic Geography—Rethinking Regional Path Dependence: Beyond Lock-in to Evolution. *Economic geography,* **86**(1), pp. 1-27.

MARTIN, R. and SUNLEY, P., 2011. Conceptualising Cluster Evolution: Beyond the Life-Cycle Model? *Papers in Evolutionary Economic Geography (PEEG)* 2011, Utrecht University, Section of Economic Geography.

MARTIN, R. and SUNLEY, P., 2010. The place of path dependence in an evolutionary perspective on the economic landscape. In: R. BOSCHMA and R. MARTIN, eds, *The Handbook of Evolutionary Economic Geography.* Cheltenham, UK and Northhampton, MA, USA: Edward Elgar, pp. 62-92.

MARTIN, R. and SUNLEY, P., 2006. Path dependence and regional economic evolution. *Journal of Economic Geography,* **6**(4), pp. 395-437.

MASKELL, P., 2001. The firm in economic geography. *Economic Geography,* **77**(4), pp. 329-344.

MENZEL, M.P. and FORNAHL, D., 2010. Cluster life cycles—dimensions and rationales of cluster evolution. *Industrial and Corporate Change,* **19**(1), pp. 205-238.

MENZEL, M.P., HENN, S. and FORNAHL, D., 2010. Emerging clusters: a conceptual overview. In: D. FORNAHL, S. HENN and M.P. MENZEL, eds, *Emerging clusters: theoretical, empirical and political perspectives on the initial stage of cluster evolution.* Cheltenham, UK: Edward Elgar Publishing, pp. 1-16.

MUNIR, K.A. and PHILLIPS, N., 2002. The concept of industry and the case of radical technological change. *The Journal of High Technology Management Research,* **13**(2), pp. 279-297.

MURMANN, J.P. and HOMBURG, E., 2001. Comparing evolutionary dynamics across different national settings: the case of the synthetic dye industry, 1857–1914. *Journal of Evolutionary Economics,* **11**(2), pp. 177-205.

NEFFKE, F., HENNING, M. and BOSCHMA, R., 2011. How do regions diversify over time? Industry relatedness and the development of new growth paths in regions. *Economic Geography,* **87**(3), pp. 237-265.

NEFFKE, F., HENNING, M., BOSCHMA, R., LUNDQUIST, K.J. and OLANDER, L.O., 2011. The dynamics of agglomeration externalities along the life cycle of industries. *Regional Studies,* **45**(1), pp. 49-65.

NELSON, R.R. and WINTER, S.G., 1982. *An evolutionary theory of economic change.* Cambridge, Massachusetts and London, England: The Belknap Press of Harvard University Press.

NOOTEBOOM, B., 2000. Learning by interaction: absorptive capacity, cognitive distance and governance. *Journal of Management and Governance,* **4**(1), pp. 69-92.

NYGAARD TANNER, A., 2014. Regional Branching Reconsidered: Emergence of the Fuel Cell Industry in European Regions. *Economic Geography,* .

PORTER, M.E., 1990. *The Competitive Advantage of Nations.* New York: The Free Press.

PORTER, M.E., 1980. *Competitive strategies: Techniques for analysing industries and competitors.* New York: Free Press.

ROGERS, E.M., 1995. *Diffusion of innovations.* Fourth edn. New York: The Free Press.

SAMPLER, J.L., 1998. Redefining industry structure for the information age. *Strategic Management Journal,* **19**(4), pp. 343-355.

SCHUMPETER, J.A., 1934. *The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle.* Transaction Publishers.

SCOTT, A.J. and STORPER, M., 1987. High technology industry and regional development: a theoretical critique and reconstruction. *International Social Science Journal,* **39**, pp. 215-232.

SÖLVELL, Ö, LINDQVIST, G. and KETELS, C., 2003. *The cluster initiative greenbook.* Stockholm: Ivory Tower Stockholm.

STORPER, M. and WALKER, R., 1989. *The capitalist imperative: Territory, technology, and industrial growth.* New York: Wiley-Blackwell.

TANNER, A.N., 2011. The Place of New Industries: the case of fuel cell technology and its technological relatedness to regional knowledge bases. *Papers in Evolutionary Economic Geography, Utrecht University,* **# 11.13**.

TANNER, A.N., 2014. Regional Branching Reconsidered: Emergence of the Fuel Cell Industry in European Regions. *Economic Geography,* .

TER WAL, A.L.J. and BOSCHMA, R., 2011. Co-evolution of firms, industries and networks in space. *Regional Studies,* **45**(7), pp. 919-933.

UTTERBACK, J.M., 1996. *Mastering the dynamics of innovation.* Harvard Business Press.

ZUCKER, L.G., DARBY, M.R. and BREWER, M.B., 1998. Intellectual human capital and the birth of US biotechnology enterprises. *American Economic Review,* **88**(1), pp. 290-306.

ZUCKER, L.G., DARBY, M.R., FURNER, J., LIU, R.C. and MA, H., 2007. Minerva unbound: Knowledge stocks, knowledge flows and new knowledge production. *Research Policy,* **36**(6), pp. 850-863.